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A Framework for Evaluating the Safety Performance of Construction Contractors

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A FRAMEWORK FOR EVALUATING THE SAFETY PERFORMANCE OF CONSTRUCTION CONTRACTORS

Abstract

Improvements to contracting organisations' safety standards could inevitably be helped by continuous monitoring and review of their safety performance. To achieve this, an objective Safety Performance Evaluation (SPE) framework is a prerequisite. Although various methods of SPE have been proposed, a more comprehensive SPE framework which takes into account factors pertinent to an organisation and its project has yet to be realised. In this paper, the importance of SPE factors is examined through a questionnaire survey conducted in Hong Kong. The results of the questionnaire survey are used to develop a SPE framework suitable for use in the construction industry and protocols for evaluating the safety performance at the organisational and project levels. Through this analytical framework, SPE scores can be computed which would facilitate the benchmarking process and various initiatives to improve the safety performance of construction contractors.

Keywords: Construction safety, safety management system, safety performance evaluation

INTRODUCTION

In a market-driven society, it is common for construction stakeholders, especially those at the lower end of the supply chain, to concentrate exclusively on completing projects to the required quality standard with the minimum time and cost. Safety is, therefore, regarded as a secondary concern. The lack of motivation in fostering a safety culture at both organisational and project levels has resulted in a poor safety record in general, with construction being one of the most hazardous industries globally (Harper and Koehn, 1997; Sawacha *et al*, 1999).

In view of the importance of Occupational Health and Safety (OHS), countries such as the United Kingdom (UK), Singapore and Hong Kong (HK) have adopted a self-regulatory approach to safety, whereby proprietors (including contractors) are required to develop, implement and maintain safety management systems (Rowlinson, 1997; Wilson and Koehn, 2000). In addition to setting out safety objectives and targets in their safety management systems, construction firms need a rational framework for Safety Performance Evaluation (SPE) in order to objectively gauge their effectiveness in accident prevention over time (*cf:* Peterson, 1980). A systematic SPE framework will also help companies to identify potential hazards at an early stage so as to help avoid unnecessary losses in life and cost.

SPE has received broad attention in the construction literature. For instance, the goal-setting and feedback method (Duff *et al*, 1994), Experience Modification Rating (EMR), Incident Rate (IR), Accident Rate (AR), and Score Card (SC) models have been proposed. Although some of these approaches have been widely used in the construction industry, a more comprehensive SPE framework which takes into account factors pertinent to an organisation and its projects is still to be realised (Ng and Tang, 2001; Sawacha *et al*, 1999).

In this paper, the importance of SPE factors is examined through a questionnaire survey conducted in Hong Kong. Based upon the identified SPE factors, a framework for establishing contractor's safety performance is presented. Finally, the potential usage of the SPE scores is discussed.

PREVIOUS RESEARCH ON SAFETY PERFORMANCE EVALUATION

Safety Evaluation Methods

Accident Rate: Despite a study conducted by Tam and Fung (1998) concluding that the use of accident rates (AR) is superior to other indices, measuring performance simply by the number of accidents has long been regarded as an unsound basis for comparison. Ccontractors diligently reporting and investigating accidents are disadvantaged in comparison with less scrupulous contractors who under-report accident occurrence (Rowlinson 1997). It is unlikely, therefore, that contractors would be sufficiently motivated to report the number of accidents accurately.

Incidence Rate: The incident rate (IR) can be computed according to the number of lost time cases (lost time IR), number of days lost for all lost time cases (severity rate or lost workday rate), and number of fatalities, injuries and illnesses with or without lost workdays (recordable IR). However, IR is not an objective means for evaluating safety performance, as different definitions may be adopted during the computation process (Jaselskis *et al* 1996). Similarly to the AR, the accuracy of IR depends on how honest a contractor is in revealing the reportable accidents, illnesses, fatalities and injuries. Also, as some construction workers are not aware of their OHS rights, they may not be in a position to claim for compensations.

Experience Modification Rating: The experience modification rating (EMR) reflects the cost companies have to pay for workers' compensation insurance. It is essentially the ratio between actual claims filed and expected claims for a particular type of construction. However, since the EMR formulae are relatively complex and different versions of calculation exist in practice (Everett and Thompson, 1995), EMR is not an appropriate measure of safety performance for all types of companies (Hinze *et al*, 1995). In addition, as the EMR is based on running average results over several years, this method cannot truly reflect the current safety performance of companies (Levitt and Samelson, 1987).

Score Card: The score card (SC) system as introduced by the HK Government consists of six key aspects: the (i) provision and maintenance of plant; (ii) provision and maintenance of the working environment; (iii) provision of information, instruction and training; (iv) provision and implementation of safety systems of work; (v) employment of safety officers/supervisors; and (vi) site accident records (Works Bureau, 2000). Weighting is allocated to each factor to reflect its importance. An assessor is required to assign a rating to each factor. However, one major weakness of the existing SC system is that it only takes into account the contractor's safety performance at a project level without considering organisation-related SPE factors. In addition, there is a lack of solid foundation as to how the weightings are established.

Factors Affecting Safety Performance

Project Level: In general, safety on construction sites is linked with historical, economical, psychological, technical, procedural, organisational and work environment issues (Sawacha *et al* 1999). The development of safety systems, safety practice and procedures; monitoring of safety compliance, establishment of safety committees at site level, communication of safety policies to site personnel, participation of safety officers, consultation between site staff and safety officers also affect the safety performance (Wong *et al*, 1999). The most effective safety techniques for projects as proposed by the Construction Industry Institute, United States include pre-project/pre-task planning for safety, safety orientation and training, and written safety incentives (Hinze and Wilson, 2000). In addition, to avoid accidents recurring on the same site, post-accident investigation systems need to be carried out to establish their causes (Tam and Fung, 1998). Other recommendations for improving safety at project level include reducing the turnover of project management teams, devoting more time to site safety issues, increasing the number of formal safety meetings with supervisors and specialty contractors, increasing informal site safety inspections, increasing fines to workers with poor safety performances, etc (Jaselskis *et al*, 1996). The project-related SPE factors are summarised in Figure 1.

< Figure 1 >

Organisational Level: The organisation's commitment to safety has a significant influence on cultivating a positive OHS culture (Ng and Tang 2001), with the most influential factor driving safety performance in the construction industry being the organisational safety policy (Sawacha *et al* 1999). Improvements in organisational structure, organisational importance of safety, safety responsibility and accountability, communication, management behaviour, employee involvement, and employee responses and behaviour can help improve safety performance (Erickson, 2000). This would involve the development of more detailed written safety programmes, greater expenditure on safety programmes, additional training to part-time safety coordinators, and better indoctrination of new staff on company policies and guidelines (Jaselskis *et al*, 1996). Safety systems, written safety policies and measurable safety targets, safety committees at company level, communication of safety policies to the various concerned parties are also said to be essential to construction safety (Wong *et al* 1999), while safety awards or incentive schemes, safety training schemes, safety committees and level of subcontracting are also recommended for consideration (Tam and Fung, 1998). Figure 2 recapitulates the SPE factors related to an organisation.

< *Figure 2* >

RESEARCH METHODOLOGY

To devise a rational framework for SPE necessitates the establishment of the importance of safety factors in an objective manner as possible. A questionnaire survey was chosen as an appropriate means for soliciting views of various project participants within a relatively short period of time. The questionnaire consists of two sections: the first section focuses on prioritising (by rank ordering) the main factors pertinent to safety performance at the organisational and project levels, while the second section aims to establish the importance of the organisation-related and project-related sub-factors shown in Figures 1 and 2. For the second part of the questionnaire, a Likert bipolar scale of 1-5 representing “very low” to “very high” was provided to help gather and analyse the level of importance of each sub-factor. The questionnaire was piloted by experts in construction safety to test the suitability of the main and sub-factors for SPE and the format of the questionnaire.

When selecting the sample for the main study, a mix of construction participants with different background was randomly sampled to minimise the possibility of bias. As a result, m three main categories of construction stakeholders were involved: (i) clients; (ii) contractors including main contractors and sub-contractors; and (iii) consultants. The questionnaire was issued to 180 potential respondents, and 129 completed questionnaires were returned, representing a response rate of 72%. Of these, 49, 41 and 39 were from the client, contractor and consultant groups respectively.

IMPORTANCE OF MAIN FACTORS

The data collected from the questionnaire survey were analysed according to the Mean Ranking (MR) and Mean Score (MS) as adopted by Assaf *et al* (1995). The MR for each main factor was computed by the following formula:

$$MR_{main\,factor} = \frac{\sum f \times r}{N}, \; (1 \leq MR \leq 7)$$

[1]

where f = frequency of responses to each rating for each main factor

r = ranking given to each main factor by the respondents

N = total number of responses concerning that factor

The MR was then used to determine the Relative Importance (RI) of each main SPE factor by:

$$RMF_j = \frac{\sum_{i=1}^{N} MR_i}{MR_j} \qquad [2]$$

where RMF_j = relative importance of j^{th} main factor

MR_j = mean ranking of j^{th} main factor

As shown in Table 1, "administrative and management commitment" is the most important main factor at the organisational level. This agrees with Tsui and Lo's (1997) findings, which were that support from management is crucial to bring about any change or improvement in construction safety. In addition, respondents also believed that it is important for contractors to offer "health and safety training" to their staff to improve workers' awareness of the potential dangers on site and use of protective equipment. In contrast, "accident record" was considered to be the least important main factor for evaluating contractor's safety performance, confirming Tang's (2001) view that the accuracy of existing statistical methods in determining the accident rate is in need of further investigation.

< Table 1 >

As for the project-related SPE main factors, "project management commitment" was rated the most important (Table 2), as a safety conscious project management team could help avoid accidents from occurring. Furthermore, since so many potential hazards exist on construction sites, "hazard management" was considered to be an important aspect by the respondents. Amongst the seven project-related main factors, "safety review" was rated the least important.

< Table 2 >

IMPORTANCE OF SUB-FACTORS

In order to establish the importance of each SPE sub-factor, the MS was computed by:

$$MS_{\text{sub-factor}} = \frac{\sum f \times s}{N}, \quad (1 \leq MS \leq 5) \qquad [3]$$

where f = frequency of responses to each rating for each sub-factor

s = score given to each sub-factor by the respondents

N = total number of responses concerning that factor

Then, the RI of each safety sub-factor was calculated as follows:

$$RSF_{ij} = \frac{MS_{ij}}{\sum_{i=1}^{N} MS_{ij}} \qquad [4]$$

where RSF_{ij} = relative importance of i^{th} sub-factor under j^{th} main factor

MS_{ij} = mean score of i^{th} sub-factor under j^{th} main factor

Table 3 summarises the MSs and rankings of the organisation-related SPE sub-factors. This shows “implementation of safety management system in accordance with legislation” to have been rated the highest. This is in line with the move of some countries towards a higher emphasis on the enforcement of the safety management system. “Compliance with occupational safety and health legislation, codes and standards” was also considered critical at an organisational level, possibly a reflection of the commitment of senior management on construction safety. Respondents rated “number of accidents happened in all construction sites” and “conduction of organisational safety policy review” the lowest in importance.

< Table 3 >

The MSs and rankings of the project-related SPE sub-factors are highlighted in Table 4 with “provision of safe working environment” being regarded as the most significant sub-factor, as accidents may be related to the tidiness of the workplace (Hill and Trist, 1954). An improvement in job conditions could help minimise the risk of accidents (Sawacha *et al*, 1999). The next most important sub-factor was the “development of emergency plan and procedures”, confirming Wong *et al*’s (1999) recent findings that safety practice & procedures were more important than other factors, as proper planning is needed in minimising the harmful consequences of an accident. On the other hand, the least important project-related sub-factors include “conduction of site safety policy review” and “implementation of safety audit to safety management system”.

< Table 4 >

DEVELOPMENT OF A SAFETY PERFORMANCE ASSESSMENT MODEL

The RI of each sub-factor and its corresponding main factor can be combined with the weight score to form a performance index. The performance index represents the score that could be assigned to each SPE factor according to the actual safety performance of a contractor. The performance index is:

$$PI_{ij} = \frac{PW \times RSF_{ij} \times RMF_j}{4} \times 100 \qquad [5]$$

where PI_{ij} = performance index of i^{th} sub-factor under j^{th} main factor

PW = weighted score of different safety performance; 1 = poor, 2 = satisfactory, 3 = good, 4 = very good

For example, the performance index for very good performance in "development of safety, for example, can be computed as follows:

RMF for company administration and management commitment = 0.249

RSF for development of safety organisation = 0.200

Weighted score for very good performance = 4

$$PI_{\text{development of safety organisation}} = \frac{4 \times 0.249 \times 0.200}{4} \times 100 = 4.98$$

Having calculated all potential index values that could be given to the sub-factors under each of the performance scenarios (i.e. from "poor" to "very good"), evaluation forms can be formulated to measure the safety performance of a contractor at the organisational (Table 5) and project levels (Table 6). With the assessment forms, an assessor can simply record the actual safety performance of a contractor based on the four rating categories of "very good", "good", "satisfactory" or "poor", and the total organisational and project-related safety scores computed by summing up the scores of all sub-factors.

< Table 5 >

< Table 6 >

As a contractor would usually have more than one project in hand, a mechanism is needed to enable the SPE scores of a series of projects to be combined. To do that, an overall project safety score can be worked out by averaging the scores of some recent projects, ie.:

$$\textit{Performance score for project level (P)} = \frac{\sum_{i=1}^{N} S_i}{N} \qquad [6]$$

where S_i = total performance score for i^{th} project

N = number of projects

The overall SPE score for a contractor is a combination of the organisation and project-related scores. However, as the weightings between the organisation and project scores depend on a company safety strategy, financial capability, policy, awareness, resources available, management's commitment, project manager and site staff's commitment and other reasons, there is no hard and fast rule to determine the ideal composition. The simplest approach is to adopt an equal weighting for the organisation and project scores as shown below:

$$Overall\ performance\ score\ =\ \frac{O\ +\ P}{2} \qquad [7]$$

where O = performance score of organisation level

P = performance score of project level

POTENTIAL APPLICATION OF SAFETY PERFORMANCE SCORE

The framework proposed is a simple and direct tool for measuring contractor's safety performance. When contractors are classified according to the SPE scores, this framework could assist decision-makers in different ways, including the determination of tendering opportunity, insurance premium, award or sanction or benchmarking performance.

Tendering opportunity: When criteria other than cost are included in the contractor selection process, the introduction of the SPE framework to could encourage contractors to put more effort into enhancing their safety performance so as to increase their tendering opportunities.

Insurance premium: It has been suggested that the feasibility be investigated of developing incentive schemes in construction insurance policies similar to the no-claim bonus commonly applied to motor insurance (Tang 2001). This will encourage contractors in maintaining a good safety record. The idea of charging contractors who have poor safety records could also help the insurance industry in reducing the payout of the employees' compensation insurance.

The proposed evaluation framework would give a more reliable index of classification pertinent to construction safety performance that can correspond to the no-claim bonus appraisal. Contractor with a higher safety performance score may therefore enjoy a discount in insurance premium.

Award or sanction: It is possible for a coordinated safety award to be made to motivate the senior management in client and contractor organisations to compete for excellence in safety. The proposed framework could provide an objective basis for categorising safety performance into different grades. The safety grading given to each contractor could also be considered as an award or recognition in itself to encourage contractors to keep monitoring and improving their safety performance.

Benchmarking performance: Safety performance on site should be benchmarked through safety inspection and perception surveys to ensure continuous improvement (Taggart and Carter 1999). Through comparison, deviations from best practice can be investigated to provide explanations of success and failure and lessons that provide the stimulus for learning, innovation and continuous improvement (Loosemore *et al*, 2001). Using the assessment framework to benchmark contractor's safety performance has great potential of fostering the improvement in OHS performance.

CONCLUSIONS

In this paper, a framework for evaluating contractors' safety performance was described. In order to facilitate a more objective framework to be developed, a range of SPE factors were identified. Thirteen of them were organisation-related while eighteen were pertinent to project level. A questionnaire survey was conducted with clients, contractors and consultants in HK in order to establish the importance of the factors. The analyses were carried out by examining the MS and MR. The results indicate the most important SPE factors at an organisational level to be "implementation of safety management system in accordance with legislation" and "compliance with occupational safety and health legislation, codes and standards". At project level, the most important SPE factor was "provision of safe working environment".

Having reviewed different existing SPE methods, a more comprehensive framework for evaluating construction safety performance was developed. This provides a comprehensive analysis approach on contractor's safety performance at both organisational and project levels that is not found in any existing systems. The safety performance scores can be used to form a league table of contractors' safety performance. This benchmarking system could be applied at tendering stage, or for determining insurance premium and award in order to enhance contractor's motivation and awareness in construction site safety.

In the light of the hitherto lack of a systematic approach to categorising contractors' safety performance, the assessment model developed as a result of this study could help more informed decisions to be made on safety performance. It could also enable contractors to identify any potential hazard at an early stage to ensure necessary measures be taken to minimise the loss in financial and social costs related to construction projects.

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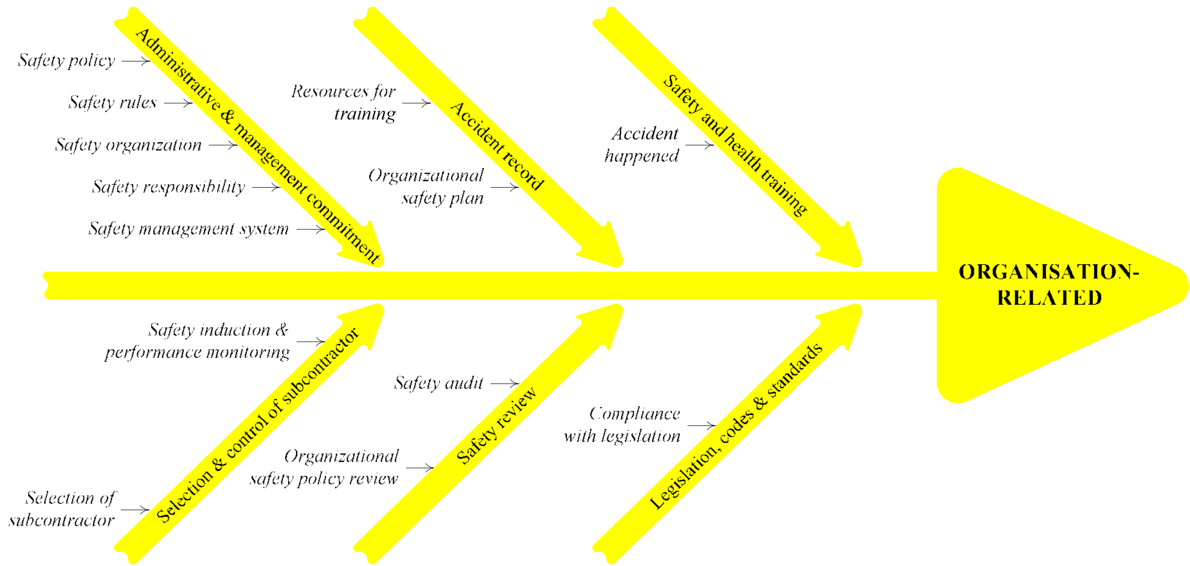

Figure 1: Safety factors in organisation level

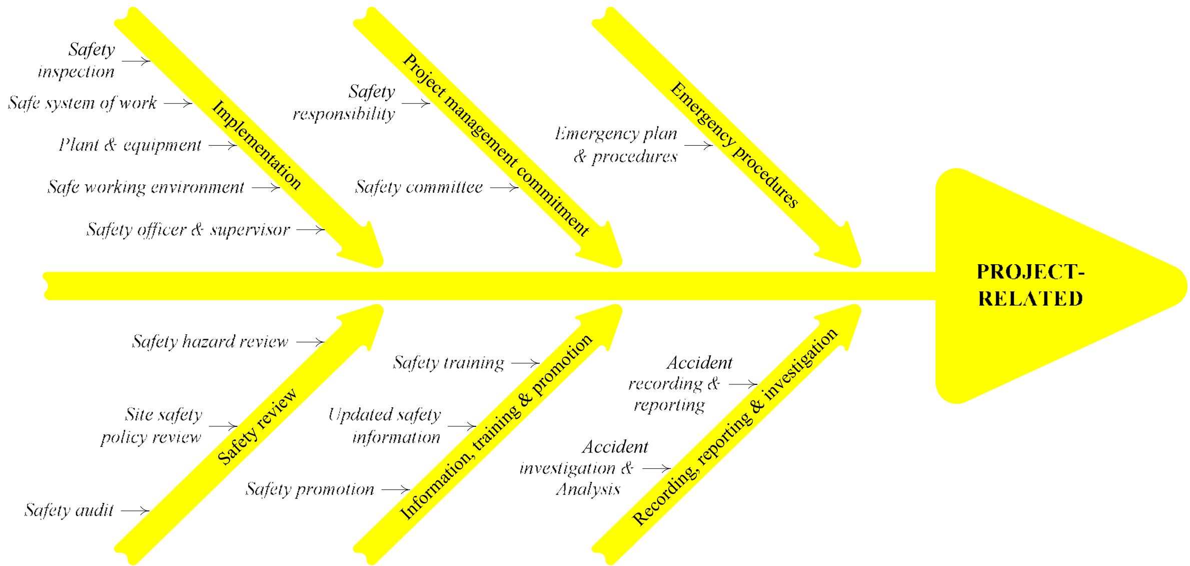

Figure 2: Safety factors in project level

Table 1: Summary of mean ranking of main organisation-related SPE factors

Factors	***MR***	***Relative ranking***	***RI***
Administrative and management commitment	2.17	1	0.249
Health and safety training	2.83	2	0.208
Legislation, codes and standards	3.04	3	0.177
Selection and control of subcontractors	3.57	4	0.152
Safety review	4.44	5	0.122
Accident record	4.95	6	0.109

Table 2: Summary of mean ranking of main project-related SPE factors

Factors	***MR***	***Relative ranking***	***RI***
Project management commitment	2.55	1	0.209
Hazard management	3.10	2	0.172
Implementation	3.42	3	0.156
Information, training and promotion	3.50	4	0.152
Emergency procedures	4.52	5	0.118
Recording, reporting and investigation	5.36	6	0.099
Safety review	5.57	7	0.096

Table 3: Relative importance of safety factors in organisation level

Main Factors / Sub-factors	***MS***	***Ranking***	***RI***
A. Administrative and Management Commitment (RI=0.25)			
Development of safety policy	3.95	4	0.200
Establishment of safety organisation	3.88	5	0.197
Definition of safety responsibility	4.01	3	0.203
Development of in-house safety rules	3.78	9	0.192
Implementation of safety management system in accordance with legislation	4.09	1	0.208
B. Health and Safety Training (RI=0.19)			
Allocation of resources for training	3.87	6	0.513
Development of organisational safety training	3.67	11	0.487
C. Selection and Control of Subcontractors (RI=0.15)			
Incorporation of safety requirement in subcontractors selection	3.84	7	0.501
Provision of safety induction and performance monitoring	3.82	8	0.499
D. Safety Review (RI=0.12)			
Implementation of safety audit to safety management system	3.72	10	0.513
Conduction of organisational safety policy review	3.53	12	0.487
E. Accident Record (RI=0.11)			
Number of accidents happened in all construction sites	3.50	13	1.000
F. Legislation, Codes and Standards (RI=0.18)			
Compliance with occupational safety and health legislation, codes and standards	4.08	2	1.000

Table 4: Relative importance of safety factors in project level

Main Factors / Sub-factors	***MS***	***Ranking***	***RI***
A. Project Management Committee (RI=0.21)			
Definition of safety responsibility to all site personnel	4.02	4	0.519
Development of safety committee	3.72	13	0.481
B. Hazard Management (RI=0.17)			
Definition of safety responsibility to all site personnel	3.98	5	0.497
Development of safety committee	4.03	3	0.503
C. Information, Training and Promotion (RI=0.15)			
Provision of safety training to all personnel	3.95	7	0.354
Provision of update safety information	3.63	14	0.326
Conduction of safety promotion	3.57	15	0.320
D. Implementation (RI=0.16)			
Provision of plant and equipment maintenance	3.95	7	0.200
Provision of safety working environment	4.10	1	0.207
Conduction of site safety inspection and supervision	3.98	5	0.201
Provision of safety systems of works	3.84	11	0.195
Employment of safety officer and safety supervisor	3.90	9	0.197
E. Recording, Reporting and Investigation (RI=0.10)			
System for accident recording and reporting	3.74	12	0.491
Conduction of accident investigation and analysis	3.88	10	0.509
F. Emergency Procedures (RI=0.12)			
Development of emergency plan and procedures	4.05	2	1.000
G. Safety Review (RI=0.10)			
Conduction of safety hazard review	3.57	15	0.336
Conduction of site safety policy review	3.53	17	0.332
Implementation of safety audit to safety management system	3.53	17	0.332

Table 5: Safety performance assessment form for organisation level

Factors	*Poor (× 1)*	*Satisfactory (× 2)*	*Good (× 3)*	*Very Good (× 4)*	*Score*
A. Administrative & Management Commitment					